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EFFECTIVE BIG DATA INTEGRATION IN THE DEVELOPMENT OF SMART CITIES IN CHINA: A DIGITAL CONTINUITY APPROACH

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Abstract:

Development of smart cities has become a national strategy for effectively tackling the challenges in current dynamic digital environment. The rapid development of smart cities leads to the production and accumulation of a huge amount of data usually referred as big data. The challenge is the accumulated data from different sources are often isolated in different information systems. It is usually very difficult or impossible to effectively and efficiently access such data from an integrated manner. Therefore, there is an increasing demand for effectively integrating and managing big data, especially in the rapid development of smart cities in China. Nevertheless, and despite a number of data integration approaches found in the literature, there is a clear lack of appropriate approach from both social construction and technological construction for the effective integration of big data sources. Moreover, there is a theoretical gap in existing integration of big data sources for explaining the multiverse of data integration in world of practice. This issue of applicability of approach is now recognised as one of the fundamental key issues in developing smart cities. This study aims at providing insights in this area, and presents a comprehensive analysis of existing studies on the integration of big data resources for the development of smart cities in China. The study employed an inductive qualitative approach based on a mix-methods strategy consisting of literature review, document analysis and case studies. The findings of this research state that the identification of four challenges in data integration and five data governance problems in the development of smart cities. To effectively tackle such challenges and adequately address these problems, a digital continuity approach, a holistic approach, is proposed to managing big data resources that data can be tracked, traced, linked and exploited for the development of smart cities in China. The proposed approach also can be used to guide the development of strategies, policies, and action plans for integrating big data resources to improve data assurance, data integrity, data trust, data security and data reusability in the delivery of smart city services in China.

Keywords:

Digital Continuity, Big Data Integration, Smart City, China

1. Introduction

A smart city is an urban system that uses information and communication technologies to make its infrastructure and public services more interactive, more accessible and more efficient (An *et al.*, 2016; Nam and Pardo, 2011). It is a city committed to its environment in which the infrastructure is equipped with the most advanced technological solution to facilitate the interaction between citizens and urban elements. Smart cities are increasingly becoming an effective approach to solve tangled problems in the rapid urbanization across the

world (Chou, 2016).

There is an increasing recognition of the importance of smart cities in China (Chou, 2016; Gu and Wang, 2014). The publication of the "National New Urbanization Plan" in 2014 (CPC Central Committee and State Council, 2014) shows that the development of smart cities has become a national strategy for effectively tackling the challenges that Chinese cities face in todays' dynamic environment. There are 373 Chinese cities that have been authorized as experimental smart cities by the Ministry of Housing and Urban-rural Development and the Ministry of Science and Technology in China. The rapid development of smart cities leads to the production and accumulation of a huge amount of data usually referred to as big data from various perspectives (Batty, 2013). Such a huge amount of data if utilized effectively can provide individual city administrations with timely and relevant information and knowledge for the effective delivery of better services (Kitchin, 2014). The challenge is that the accumulated data from different sources are often isolated in different information systems (An *et al.*, 2014; Goodhue *et al.*, 1992). It is usually difficult, if not impossible, to effectively and efficiently access such data in an integrated manner. As a result, the effective management of such a huge amount of data is critical for the development of smart cities in China.

Digital continuity is an ecosystem approach to enable the competence of digital governance, digital ability and digital services building for maintaining the digital information in a way that such information is available when needed despite the changes in the adoption of digital technologies (An *et al.*, 2016; NAA, 2014; Cochrane, 2010). It is widely used in various organizations and individual countries across the world for (a) optimizing the delivery of public programs and services, (b) enabling information reuse for economic and social benefits, and (c) protecting the rights and entitlements of citizens (NAA, 2014; Gatenby, 2002). Digital continuity provides various governments with a consistent approach to information governance in the presence of big data sources across various organizations with respect to the management and utilization of data and information, as well as systems, services and processes in the development of smart cities.

This paper presents a digital continuity approach for managing big data sources in the development of smart cities in China. A mix-methods approach including document analysis, case study, site visits and interviews is adopted in the study. This leads to the identification of four challenges with respect to data provenance, data stakeholders, data processing and data risk management and five problems including data assurance, data loss, data trust, data security and data reusability in the development of smart cities through effective big data integration in China. To effectively tackle such challenges and adequately address these problems, a digital continuity approach is proposed for effectively managing big data resources in developing smart cities in China.

2. A review of literature

There are various ways to approach the development of smart cities in the existing literature (Giffinger *et al.*, 2007), for example, consider a smart city as "a city well-performing in a forward-looking way in various characteristics, built on the smart combination of endowments and activities of self-decisive, independent and aware citizens". Hall (2000) describes a smart city as "a city that monitors and integrates conditions of all of its critical infrastructures". Hartley (2005) treats a smart city as a city "connecting the physical infrastructure, the IT infrastructure, the social infrastructure, and the business infrastructure to leverage the collective intelligence of the city". Toppeta (2010) states that a smart city is a city "combining information and communication technologies and Web 2.0 technologies with

other organizational, design and planning efforts to de-materialize and speed up bureaucratic processes and help to identify innovative solutions to city management in order to improve sustainability and livability". More importantly, three major international standard organisations provide much more detailed expression on smart cities, for instance, ISO is focusing on "strategic management" of collaborative leadership for working across disciplines and city systems and data and technology integration, ITU-T prefers to use ICTs to achieve needs of present and future generations; efficiency of operations and urban service; sustainable and productivity competitiveness, and IEC exploits the transformation power of data and technology for the interests of future generations; better service effective transformation in smart cities (An, Mulquin, Song, 2017).

Nevertheless, development of smart cities in China is going from technology-dominant information infrastructure building to big data driven management thinking (Yang, Fan and Lai, 2015; Chou, 2016). It is moving towards the provision of people-centric cyber-infrastructure services (Chen, Wang and Guo, 2016). As a result, the smart city development research needs the adoption of a multidisciplinary perspective with pluralistic thinking.

Although the view of literature shows there are a variety of approaches to data integration in the development of smart cities in China. Little attention is paid to the adoption of a data continuity approach to enable data assurance, data integrity, data trust, security and reusability along the life of data in the development of smart cities from the perspective of information resources management (Alawadhi *et al.*, 2012). This shows that there is a need to study digital continuity in the development of smart cities, which is vital to maintain the digital data in such a way that the digital transformation is paperless with the information management competence to ensure the digital data is trusted, secure, available and usable when needed despite changes in the adoption of various digital technologies over the time.

3. Research Methodology

This paper aims to bridge the theoretical gap in the integration of big data sources for the sustainable development of smart cities in China. It aims to propose develop a digital continuity approach as a social construct as well as a technological construct for effective data integration in developing smart cites in China. In order to achieve the aims, the main research question is developed as follows:

> *How to facilitate effective big data integration in the development of smart cities in China?*

In order to answer such question, a mix-methods approach consisting of literature review, document analysis and case studies is adopted. Literature review is used to identify representative perspectives and schools of thoughts from existing studies related to the integration of data sources in the development of smart cities. Important databases including China Journal Net Database, ProQuest Database, EBSCO database, Web of Science, Baidu Scholar and google scholar are searched with the use of common terms such as 'data integration", "smart city development", "data and information resources management". Document analysis is used to justify the demand for digital continuity approach through an examination of existed national polices and plans issued by the State Council, the CPC Central Committee and State Council, and the National Development and Reform Commission of China etc. Case studies are used to support evidence-based arguments from website visits, and field studies, and to collect data for diagnosing real world challenges and

problems for big data integration in developing smart cities in China.

4. Digital continuity in developing smart cities

Digital continuity is an integration process for ensuring digital data to be qualified with integrity, trustiness, security and reusability in the provision of smart city services along the entire data life cycle (An *et al.*, 2016). It aims to provide a holistic approach for sharing and reusing data in order to continually deliver smart city services despite the changes in the adoption of digital technologies based on comprehensive information resources mapping, building, operating and management across localities, administrative levels, systems, sectors and businesses (An, Deng and Zhang, 2014; An *et al.*, 2016; Dallas, 2015).

UK is the first country to start the "Digital Continuity" initiative in the world. It treats digital continuity as the ability to ensure that data and information are available in a timely manner and opened in a readable form, complete with the context and an assured quality, usable as required with the user's available technologies (NAUK, 2013; 2015).

New Zealand is the second country that considers digital continuity as a national strategy for the development of smart cities. It defines digital continuity as "the ability to ensure digital information is accessible and usable by those that need it for as long as it is needed" (SSC, 2015).

Australia is the third country that has developed a digital continuity plan nationally. Digital continuity is become a consistent approach for information governance across individual agencies in the Australian public sector (NAA, 2011).

In US all permanent data and information in Federal agencies are managed electronically to the fullest extent possible (EOP, 2012). The US digital continuity mechanism focuses on information systems development processes for automated and secured information resources management.

An analysis of existing documents in China reveals that there is lack of a national strategy for digital continuity for the development of smart cities. Currently, those official policies strongly argue for effective data integration to facilitate data sharing, to enable public services, and to support smart city developments through the adoption of big data technologies. To ensure the effective integration of big data resources, there is a need for adopting a whole government approach to manage data as strategic assets along their entire life cycles. As a result, a comprehensive study of the adoption of a digital continuity approach for the development of smart cities in China is necessary.

5. Discussion

5.1 Challenges from data integration in the development of smart cities

There are four challenges that are emerged on data resources management for data integration in the development of smart cities including data sources, data stakeholders, data processing activities and data risk management.

The first challenge is on the change of data sources that creates the need for data quality assurance in the process of integrating big data sources. There is an increasing need for ensuring the consistency of data quality across systems and platforms to facilitate the effective integration of big data sources in the development of smart cities in China (An *et al.*, 2016).

The second challenge is on the change of data stakeholders that creates an issue of data trust for big data integration in developing smart cities (Ferguson, 2012; Khan *et al.*, 2015; An *et al.*, 2016). Integrating big data sources is facing challenges in assuring the trustiness of big data as evidences, memories, identities and assets to facilitate data sharing through open data in the development of smart cities.

The third challenge is about the change of data processing activities that asks for data continuity in the integration of big data sources for the development of smart cities. The process of data acquisition, however, is changing from a single data source to multiple formats and multiple data sources, from static data to real time data, from structured data to non-structured data (Ferguson, 2012; An *et al.*, 2016). Data storage is changing from distributed cold storage to centralized cloud storage. Data use is changing from open access to public information to open pubic data. To ensure the effective integration of big data sources in the delivery of such services, there is a need for ensuring data continuity.

The fourth challenge is from the change of data risks that calls for effective data risk management in the process of integrating big data sources towards the development of smart cities. With the rapid development of smart cities through the application of big data technologies, there is a risk of divulge of the privacy and the identity of individuals through data integration (Khan, Pervez and Ghafoor, 2014; An *et al.*, 2016).

5.2 A digital continuity approach for data integration

To effectively tackle those challenges, there is an increasing demand for a digital continuity approach for data integration in the development of smart cities in China.

At the city level, digital continuity refers to the digital ability to ensure and protect trust, security, privacy, usability of data across government departments and organizations in a networked environment for smart city development to support online culture, digital life and paperless office of citizens. Such a proposition is the outcome of a synergy between the New Zealand model of managing digital records as social resources and the US model of innovation of automated electronic records management system for dealing with the challenge of multiple data stakeholders in the integration of big data sources for the development of smart cities.

At the organizational level, digital continuity enables the provision of smart city services of public organizations through adequately managing changes and risks in a totally digitalized world and developing technologies that enable records and information created, stored and used in a digital format. Such a proposition is resulted from the convergence of the UK model of managing digital records as digital asset to avoid risk and the US model of managing digital records as strategic asset for effectively tackling the challenges of multiple data sources and data risks in the integration of big data sources for the development of smart cities.

At the business level, digital continuity enables the adoption of a proactive and optimized information governance approach to ensure authenticity, reliability, integrity and usability of data in the provision of smart city services through big data integration. Such a proposition is the combination of the New Zealand model of regulatory requirements for recordkeeping embedded in e-government service and the Australia model of digital transition strategy embedded in e-governance for appropriately addressing the challenges of complex data

processing in the integration of big data sources for the development of smart cities.

Therefore, the development of a meta-synthetic strategy of digital continuity for data integration would provide a meta-synthetic digital governance approach to adequately deal with the changes of data sources, data stakeholders, data processing activities and data risk management in the development of smart cities in China.

6. Conclusion

This paper rationalizes the necessities for a digital continuity approach for data integration in the development of smart cities in China. It promotes pluralistic thinking about multiverse of data integration in developing smart cities. It provides a digital continuity approach to map digital abilities, build digital services and use digital approaches for better governance, optimized information resources management, sustainable ecosystems and collaborative social innovation in the delivery of smart city services. Such approach can ensure the accountability, transparency, green environment, innovative technology, and better public services in the development of smart cities. The proposed approach can be used to guide the development of a national strategy for the integration of big data resources in the development of smart cities in China.

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